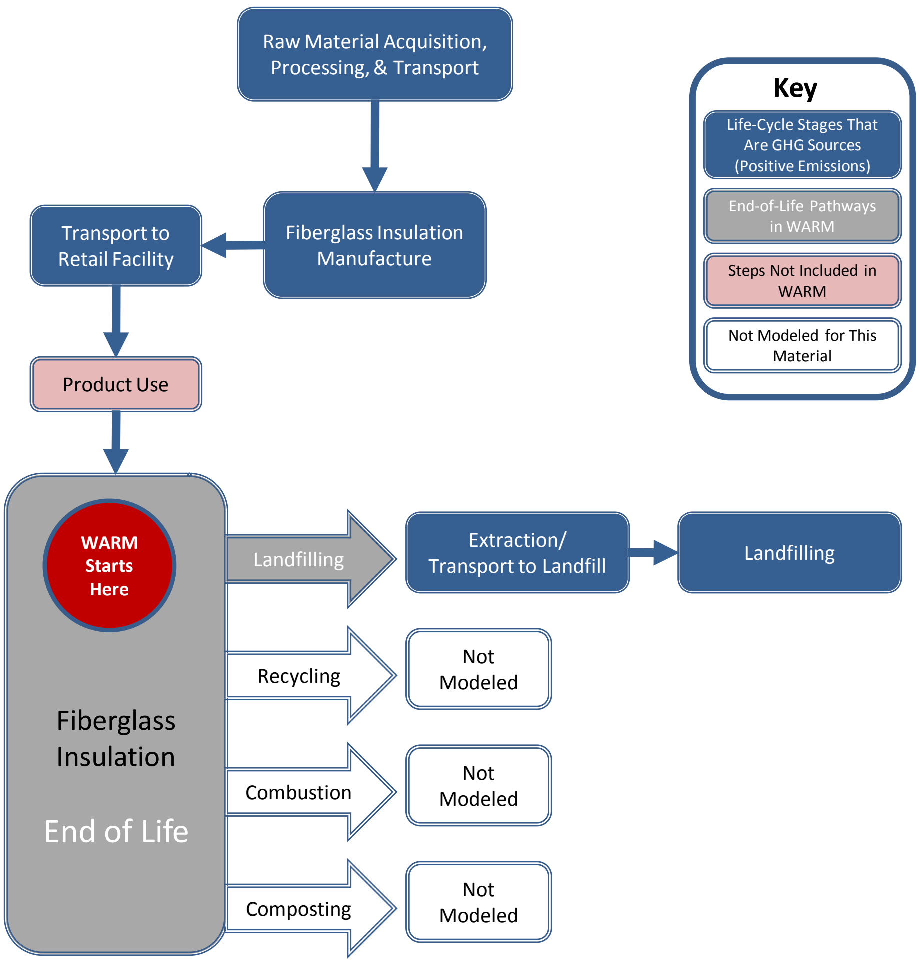
FIBERGLASS INSULATION

1. INTRODUCTION TO WARM AND FIBERGLASS INSULATION

This chapter describes the methodology used in EPA's Waste Reduction Model (WARM) to estimate streamlined life-cycle greenhouse gas (GHG) emission factors for fiberglass insulation beginning at the waste generation reference point.[1] The WARM GHG emission factors are used to compare the net emissions associated with fiberglass insulation in the following two waste management alternatives: source reduction and landfilling. Exhibit 1 shows the general outline of materials management pathways for fiberglass insulation in WARM. For background information on the general purpose and function of WARM emission factors, see the General Guidance chapter. For more information on Source Reduction and Landfilling, see the chapters devoted to those processes. WARM also allows users to calculate results in terms of energy, rather than GHGs. The energy results are calculated using the same methodology described here but with slight adjustments, as explained in the Energy Impacts chapter.

Exhibit 1: Life Cycle of Fiberglass Insulation in WARM



WARM models fiberglass batt insulation, which is often used in building walls and ceilings for its thermal insulating properties. Fiberglass batt insulation is sold under a variety of thicknesses and densities, which offer different thermal resistance values (R-values). The WARM factors are based on weight (short tons), rather than thickness or square foot, of insulation and therefore are not specific to any particular R-value type of insulation.

[1] EPA would like to thank Mr. Scott Miller of Knauf Insulation for his efforts at improving these estimates.

2. LIFE-CYCLE ASSESSMENT AND EMISSION FACTOR RESULTS

The life-cycle boundaries in WARM start at the point of waste generation, or the moment a material is discarded, as the reference point and only consider upstream GHG emissions when the production of new materials is affected by materials management decisions. Recycling and Source Reduction are the two materials management options that impact the upstream production of materials, and consequently are the only management options that include upstream GHG emissions. For more information on evaluating upstream emissions, see the chapters on Recycling and Source Reduction.

WARM only has emission factors for landfilling and source reduction for fiberglass insulation. Fiberglass insulation is neither combusted nor composted. It *is* reusable in that it can be easily removed and re-installed (NAIMA, 2007); the extent to which this is actually done, however, is not known. As Exhibit 2 illustrates, all of the GHG sources and sinks relevant to fiberglass insulation in this analysis are contained in the raw materials acquisition and manufacturing (RMAM) and materials management sections of the life cycle.

Exhibit 2: Fiberglass Insulation GHG Sources and Sinks from Relevant Materials Management Pathways

Materials Management Strategies for Fiberglass Insulation	GHG Sources and Sinks Relevant to Fiberglass Insulation		
	Raw Materials Acquisition and Manufacturing	**Changes in Forest or Soil Carbon Storage**	**End of Life**
Source Reduction	**Offsets** • Acquisition of raw materials • Transport of raw materials and products • Manufacture process energy • Manufacture process non-energy	NA	NA
Recycling	Not modeled in WARM		
Composting	Not applicable because fiberglass insulation cannot be composted		
Combustion	Not modeled in WARM		
Landfilling	NA	NA	**Emissions** • Transport to construction & demolition landfill • Landfilling machinery

NA =Not applicable.

WARM analyzes all of the GHG sources and sinks outlined in Exhibit 2 and calculates the net GHG emissions per short ton of fiberglass insulation. For more detailed methodology on emission factors, please see the sections below on individual waste management strategies. Exhibit 3 outlines the net GHG emissions for fiberglass insulation under each materials management option.

Exhibit 3: Net Emissions for Fiberglass Insulation under Each Materials Management Option ($MTCO_2E$/Short Ton)

Material/Product	Net Source Reduction (Reuse) Emissions for Current Mix of Inputs	Net Recycling Emissions	Net Composting Emissions	Net Combustion Emissions	Net Landfilling Emissions
Fiberglass Insulation	-0.39	NA	NA	NA	0.04

NA =Not applicable.

3. RAW MATERIALS ACQUISITION AND MANUFACTURING

For fiberglass insulation, the GHG emissions associated with raw materials acquisition and manufacturing are (1) GHG emissions from energy used during the acquisition and manufacturing processes, (2) GHG emissions from energy used to transport materials, and (3) non-energy GHG emissions resulting from manufacturing processes. Process non-energy GHG emissions occur during the manufacture of certain materials and are not associated with energy consumption.

Fiberglass insulation is produced using recycled glass cullet, sand, soda ash, limestone, borax and binder coatings. Exact proportions of these materials can vary. Fiberglass can be made using 100 percent virgin inputs (i.e., no recycled glass cullet), although most manufacturers do include recycled cullet in their manufacturing processes.

Exhibit 4 shows the proportion of materials assumed in WARM; this calculation was derived using Lippiatt (2007) and Miller (2010). Fiberglass generally uses cullet from recycled plate glass, but the Glass Packaging Institute (cited in NAIMA, 2007, p. 5) notes that "fiberglass insulation is the largest secondary market for recycled glass containers."

Exhibit 4: Material Composition of Fiberglass, by Weight

Material	% Composition of Fiberglass
Recycled Glass Cullet	40%
Sand	28%
Soda Ash	11%
Limestone	8%
Borax	8%
Binder Coatings	5%

Source: Derived from Lippiatt (2007) and Miller (2010).

The fiberglass insulation production process is similar to the production process for glass containers described in the Glass chapter. However, instead of being formed into molds, the molten glass is spun into fibers, and glass coatings are added. The product is then sent through a curing oven and cut to the appropriate size. Making fiberglass insulation from recycled cullet requires less energy than making it from sand and other raw materials, since it avoids the energy needed to fuse the raw materials into glass. For every 10 percent of recycled content in fiberglass insulation, the manufacturing energy needs decrease by roughly 3.25 percent (Miller, 2010).

The RMAM calculation in WARM also incorporates "retail transportation," which includes the average truck, rail, water and other-modes transportation emissions required to transport fiberglass insulation from the manufacturing facility to the retail/distribution point, which may be the customer or a variety of other establishments (e.g., warehouse, distribution center, wholesale outlet). The energy and GHG emissions from retail transportation are presented in Exhibit 5, and are calculated using data on average shipping distances and modes from the U.S. Census Bureau (2007) and on typical transportation fuel efficiencies from EPA (1998). Transportation emissions from the retail point to the consumer are not included.

Exhibit 5: Retail Transportation Energy Use and GHG Emissions

Material/Product	Average Miles per Shipment	Transportation Energy per Short Ton of Product (Million Btu)	Transportation Emission Factors ($MTCO_2E$/ Short Ton)
Fiberglass Insulation	388	0.42	0.03

4. MATERIALS MANAGEMENT METHODOLOGIES

This analysis considers source reduction and landfilling pathways for materials management of fiberglass insulation. Source reduction results in net negative emissions (i.e., a net reduction in GHG emissions), while landfilling results in slightly net positive emissions.

4.1 SOURCE REDUCTION

When a material is source reduced, GHG emissions associated with making the material and managing the postconsumer waste are avoided. As discussed previously, under the measurement convention used in this analysis, source reduction for fiberglass insulation has negative raw material and manufacturing GHG emissions (i.e., it avoids baseline emissions attributable to current production) and zero materials management GHG emissions. For more information, please refer to the module on Source Reduction.

Exhibit 6 outlines the source reduction emission factor for fiberglass insulation. GHG benefits of source reduction are calculated as the emissions savings from avoided raw materials acquisition and manufacturing (see section 3) of fiberglass insulation produced from a “current mix” of virgin and recycled inputs. Fiberglass insulation is usually not manufactured from 100 percent virgin inputs, and is rarely manufactured from 100 percent recycled inputs. WARM assumes that, on average, the “current mix” of fiberglass is composed of 40 percent recycled glass content.

Exhibit 6: Source Reduction Emission Factors for Fiberglass Insulation ($MTCO_2E$/Short Ton)

Material	Raw Material Acquisition and Manufacturing for Current Mix of Inputs	Raw Material Acquisition and Manufacturing for 100% Virgin Inputs	Forest Carbon Storage for Current Mix of Inputs	Forest Carbon Storage for 100% Virgin Inputs	Net Emissions for Current Mix of Inputs	Net Emissions for 100% Virgin Inputs
Fiberglass Insulation	-0.39	-0.50	NA	NA	-0.39	-0.50

NA = Not applicable.

Post-consumer emissions are the emissions associated with materials management pathways that could occur at end of life. There are no post-consumer emissions from source reduction because production of the material is avoided in the first place, and the avoided material never becomes post-consumer. Forest carbon storage is not applicable to fiberglass insulation, and thus does not contribute to the source reduction emission factor.

Please note that source reduction of fiberglass does not necessarily imply less insulating of buildings. Rather, source reduction could come from reuse of insulation or other means. The WARM factors do not consider how the source reduction would occur, or the GHG implications of using less or different types of insulation.

4.1.1 Developing the Emission Factor for Source Reduction of Fiberglass Insulation

To produce fiberglass insulation, energy is used both in the acquisition of raw materials and in the manufacturing process itself. In general, the majority of energy used for these activities is derived from fossil fuels. Combustion of fossil fuels results in emissions of CO_2. In addition, manufacturing fiberglass insulation also results in process non-energy CO_2 emissions from the heating of carbonates (soda ash and limestone). Hence, the RMAM component consists of process energy, non-process energy and transport emissions in the acquisition and manufacturing of raw materials, as shown in Exhibit 7. Please note that the tables in this section reflect the “current mix” of inputs, as fiberglass insulation usually contains recycled glass cullet.

Exhibit 7: Raw Material Acquisition and Manufacturing Emission Factor for Virgin Production of Fiberglass Insulation ($MTCO_2E$/Short Ton)

(a) Material/Product	(b) Process Energy	(c) Transportation Energy	(d) Process Non-Energy	(e) Net Emissions (e = b + c + d)
Fiberglass Insulation	-0.28	-0.06	-0.15	-0.50

Avoided Process Energy. To calculate this factor, EPA first obtained an estimate of the amount of energy required to acquire and produce one short ton of fiberglass insulation. Lippiatt (2007) provides estimates on the percent of each of the raw materials needed for manufacturing fiberglass, which include borax, soda ash, limestone, sand, glass cullet and binder coatings; EPA adjusts these percentages to increase the portion of recycled cullet from 34 to 40 percent, based on information received from Miller (2010). EPA obtained raw material acquisition data from the National Renewable Energy Laboratory (NREL, 2009) for soda ash and limestone, and from Athena (2000) for sand. NREL also provided estimates for borax, but these estimates include energy requirements of the infrastructure that were outside the boundaries of a WARM analysis; therefore, WARM allocates the fraction of borax in fiberglass among soda ash, limestone and sand on a proportional basis. Lippiatt (2007) also provides information on binder coatings. However, binder coatings represent a small component of fiberglass insulation (5 percent), and additional information on binder coating manufacture was not available;

therefore, WARM does not include binder coatings in this analysis. NREL (2009), Lippiatt (2007) and Athena (2000) all provided energy estimates by fuel type.

Next, we multiply the fuel consumption (in Btu) by the fuel-specific carbon content. The sum of the resulting GHG emissions by fuel type comprises the total process energy GHG emissions, including both CO_2 and CH_4, from all fuel types used in fiberglass insulation production. The process energy used to produce fiberglass insulation and the resulting emissions are shown in Exhibit 8.

Exhibit 8: Process Energy GHG Emissions Calculations for Virgin Production of Fiberglass Insulation

Material/Product	Process Energy per Short Ton Made from Virgin Inputs (Million Btu)	Process Energy GHG Emissions ($MTCO_2E$/Short Ton)
Fiberglass Insulation	4.74	0.28

Avoided Transportation Energy. Transportation energy emissions occur when fossil fuels are used to transport raw materials and intermediate products for fiberglass insulation production. The methodology for estimating these emissions is the same as the one used for process energy emissions. EPA obtained transportation distances of raw materials from Lippiatt (2007). The assumed current mix of raw material inputs (including glass cullet) indicates that the materials are transported approximately 187 miles on a weighted average basis. EPA assumes they are transported by truck, and applies the standard WARM estimate of 0.0118 gallons diesel consumed per ton-mile. We estimated retail transportation using U.S. Census Bureau (2007), as shown in Exhibit 5. The calculations for estimating the transportation energy emission factor are shown in Exhibit 9.

Exhibit 9: Transportation Energy Emissions Calculations for Virgin Production of Fiberglass Insulation

Material/Product	Transportation Energy per Short Ton Made from Virgin Inputs (Million Btu)	Transportation Energy GHG Emissions ($MTCO_2E$/Short Ton)
Fiberglass Insulation	0.44	0.03

Note: The transportation energy and emissions in this exhibit do not include retail transportation, which is presented separately in Exhibit 5.

Avoided Non-Process Energy. Non-energy GHG emissions occur during manufacturing but are not related to consuming fuel for energy. For fiberglass insulation, non-energy CO_2 emissions (based on data from ICF (1994)) are emitted in the virgin glass manufacturing process during the melting and refining stages from the heating of carbonates (soda ash and limestone). This number is then multiplied by 95 percent, which is the approximate glass content of fiberglass insulation, and then by 60 percent, the approximate content of the glass that comes from raw materials. Exhibit 10 shows the components for estimating process non-energy GHG emissions for fiberglass insulation.

Exhibit 10: Process Non-Energy Emissions Calculations for Virgin Production of Fiberglass Insulation

Material/Product	CO_2 Emissions (MT/Short Ton)	CH_4 Emissions (MT/Short Ton)	CF_4 Emissions (MT/Short Ton)	C_2F_6 Emissions (MT/Short Ton)	N_2O Emissions (MT/Short Ton)	Non-Energy Carbon Emissions ($MTCO_2E$/Short Ton)
Fiberglass Insulation	0.15	–	–	–	–	0.15

– = Zero emissions.

4.2 RECYCLING

While fiberglass insulation could be recycled in theory, it generally is not done (Crane, 2009). Because fiberglass is light, the amount of glass recovered in a given truckload would be relatively small, and much of the energy savings from recycling the fiberglass would be lost through the transportation processes (Miller, 2009). However, fiberglass is a major market for recycled glass, so it can be viewed as an open-loop pathway for glass recycling. WARM does not include this open-loop pathway for glass at this time, as EPA could not locate sufficient information to develop the pathway during development.

4.3 COMPOSTING

Fiberglass is not subject to aerobic bacterial degradation, and therefore, cannot be composted. Therefore, EPA does not include an emission factor in WARM for the composting of fiberglass insulation.

4.4 COMBUSTION

Fiberglass is generally not combusted, thus EPA does not include an emission factor in WARM for the combustion of fiberglass insulation.

4.5 LANDFILLING

Landfill emissions in WARM include landfill methane and carbon dioxide from transportation and landfill equipment. WARM also accounts for landfill carbon storage, and avoided utility emissions from landfill gas-to-energy recovery. However, since fiberglass insulation does not contain biodegradable carbon, there are zero emissions from landfill methane, no landfill carbon storage, and zero avoided utility emissions associated with landfilling fiberglass insulation. Greenhouse gas emissions associated with RMAM are not included in WARM's landfilling emission factors. As a result, the landfilling emission factor for fiberglass is equal to the GHG emissions generated by transportation to the landfill and operating the landfill equipment. The landfilling emission factor for fiberglass insulation is summarized in Exhibit 11. For more information, please see the chapter on Landfilling.

Exhibit 11: Landfilling Emission Factor for Fiberglass Insulation ($MTCO_2E$/Short Ton)

Material	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Landfill	Landfill CH_4	Avoided CO_2 Emissions from Energy Recovery	Landfill Carbon Storage	Net Emissions (Post-Consumer)
Fiberglass	–	0.04	–	–	–	0.04

– = Zero Emissions.

5. LIMITATIONS

Although this analysis is based upon best available life-cycle data, it does have certain limitations. EPA was unable to obtain sufficient life-cycle information on the raw material acquisition of borax, which represents about 8 percent of fiberglass raw materials by weight. Therefore, the analysis does not account for the emissions associated with obtaining and processing borax.

Furthermore, drywall contains a small amount of binder coatings—materials for which EPA was unable to obtain life-cycle information. Therefore, EPA's analysis does not consider the life-cycle GHG impact of binder coatings, which represent about 5 percent of fiberglass insulation by weight.

6. REFERENCES

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